LPR 1710.6
Effective Date: July 22, 2004
Expiration Date: January 22, 2005

LANGLEY RESEARCH CENTER

ELECTRICAL SAFETY

National Aeronautics and Space Administration

Responsible Office: **Office of Safety and Mission Assurance**

LPR 1710.6

PREFACE

These procedural requirements, part of the Langley Research Center (LaRC) Safety Manual, sets forth minimum electrical safety guidelines and standards within the framework of LaRC safety policies and constraints. It is for use by professionals routinely engaged in electrical work. It is not an instruction manual for untrained personnel nor is it a substitute for detailed procedures judged necessary for the safe conduct of a specific task by individuals and their supervisors.

LHB 1710.6, dated June 1994, is rescinded and should be destroyed.

Wallace C. Sawyer
Deputy Director

DISTRIBUTION:
SDL 040, SDL 043, SDL 410, SDL 411, and SDL 412 (LaRC Safety Manual Holders)
429/Office of Safety and Facility Assurance, OSMA (200 copies)

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1. INTRODUCTION

These procedural requirements contain both guidance and requirements for the assurance of safe working environments for professionals routinely engaged in electrical work at Langley Research Center (LaRC). The requirements are applicable to all NASA employees and to all other agencies, organizations, and contractor personnel who perform work at LaRC.

2. GENERAL SAFETY

2.1 CONFORMANCE WITH CODES, REGULATIONS, AND STANDARDS

The recommendations of established codes, regulations and standards shall be followed. These are listed as follows with a brief description of their general coverage:

- Occupational Safety and Health Act (OSHA) - This regulation covers conditions, practices, or operations to assure safe and healthful work places.
- National Electrical Code (NEC) - This code covers electrical conductors and equipment installed within or on public and private buildings and other premises.
- National Electrical Manufacturer's Association (NEMA) - These standards cover electrical power equipment including standard ratings, performance, testing, manufacturing, and marking.
- Electronic Industries Association (EIA) - These standards cover electronic-type electrical equipment and components.
- The Insulated Power Cable Engineers Association (IPCEA) and Association of Edison Illuminating Companies (AEIC) - These standards cover insulated power, control, and communication cable.
- Institute of Electrical and Electronic Engineers, Inc. (IEEE) - These standards consist of technical reports, testing procedures generally used in electrical power generation, distribution, and utilization.
- American National Standard Institute (ANSI) - These standards are a cataloging of new and existing standards under a common file system. The ANSI standard often has dual cataloging designations.
- Instrument Society of America (ISA) - These standards and recommendations cover the development and application of industrial instrumentation and process controls.

2.2 IMPLEMENTATION OF THE NATIONAL ELECTRICAL CODE

The National Electrical Code (NEC) is revised and a new edition is issued on a 3-year cycle. The policy for implementation of the revised edition of the NEC for use at LaRC is:

- The Chairperson, Electrical Systems Committee (ESC), will issue a memorandum establishing the date of implementation for all new editions of the NEC. (See LAPD 1150.2, “Boards, Panels, Committees, Councils, and Teams.”)
- There is no general provision in the NEC requiring any NEC changes or updates to be retroactive. Therefore, the upgrade of an electrical system merely to meet the changed NEC is not required.
- The revised NEC requirements should immediately be implemented if the implementation will improve the safeguarding of personnel or will protect LaRC

equipment. Such determinations will be made in consultation with the Office of Chief Counsel, the Systems Engineering Competency and the Office of Safety and Mission Assurance.

- The requirements of the latest adopted version of the NEC shall be used for all new electrical work unless there are more stringent requirements imposed by LaRC policy.
- If a facility is being constructed when the new NEC is adopted, the ESC will evaluate the new NEC requirements and determine if there are reasons to incorporate any changes into the construction contract. If so, the ESC will issue a memorandum to the appropriate line organizations requesting that these changes be incorporated into the contracts.
- Electrical equipment which is modified should be brought up to the requirements of the latest version of the NEC unless the modifications to the equipment do not significantly change the function or design of the system. Electrical wiring and equipment that is not included in the modification does not have to be updated.

2.3 LINE ORGANIZATION

The duties, functions, and responsibilities of Facility Safety Heads and Facility Coordinators are as set forth in LAPD 1700.2, “Safety Assignments.”

2.4 GENERAL SYSTEM SAFETY RULES

Before commencing work on any mechanical equipment or systems which have electrical connections or contain explosive, combustible, or other dangerous gases or fluids, the equipment or systems are to be properly grounded (see Chapter 6.5) and/or made safe in accordance with other LaRC safety regulations concerning these materials.

No work (other than performing routine electrical tasks such as taking electrical measurements, replacing plug-in components, or changing fuses, lamps, and circuit breakers) shall be performed on energized power circuits of 600 volts or less without prior authorization from the worker's line supervisor. When such work is necessary, a documented procedure shall be established and approved by the line supervisor and the work shall be performed only by electrically qualified personnel.

The buddy system, a second electrically qualified person directly observing the operation, is mandatory whenever electrical work (including measurements) is to be performed on energized circuits of 601 volts (phase-to-phase) or higher except as follows:

- An instructed person may accompany electrical personnel in lieu of an electrically qualified person when work such as switching or tagging is being performed.
- An electrically qualified person may be authorized by their line supervisor to take meter readings without the presence of a second person.

An instructed electrical person shall be present when nonelectrical work such as grounds keeping is being performed in an energized substation.

Safety glasses or goggles shall be worn when making electrical measurements, inspecting internal wiring of panels, or working with tools in close proximity to any energized power circuits. Safety glasses or goggles should be worn when performing other types of electrical work including control modification and/or checkout.

Fuses shall not be removed on energized circuits above 23,000 volts. Fuses shall not be removed from loaded energized circuits with voltage ranges from 50 volts to 23,000 volts. Procedures to be used when removing or replacing fuses on unloaded energized circuits shall conform to the following for circuits:

- Rated 50 to 600 volts, insulated fuse tongs, extractors, or other approved methods shall be used.
- Rated 601 to 1000 volts, lineman's type rubber gloves in addition to either insulated fuse tongs or extractors shall be used.
- Rated 1001 to 23,000 volts, lineman's type rubber gloves in addition to insulated high-voltage sticks or tongs shall be used.

Identification markings on building light and power distribution panels, circuits, and components shall not be relied on for establishing safe work conditions.

Exposed energized circuits are not to be approached closer than the following distances, for any reason, unless such parts are adequately guarded:

Alternating Current Voltage Range - Phase-to-Phase	**Minimum Distances**
601 - 10,000 volts	2 feet
10,001 - 50,000 volts	3 feet
50,001 - 115,000 volts	5 feet

Ground wires or connections to frames or cases are not to be removed from any energized equipment.

Earth return is not to be used in the wiring of any power circuit.

Temporary electrical wiring is not to be run directly on ungrounded conductive surfaces but is to be supported by suitable wood or other insulating materials. Temporary electrical wiring and portable electrical cords are to be kept out of water at all times unless the cable is approved by the NEC for that purpose.

The user of lineman's type rubber gloves shall ensure that the gloves are tested at least every 180 days for the circuit voltages involved in accordance with ANSI/ASTM

F496-91 “Standard Specification for the In-Service Care of Insulating Gloves and Sleeves.” In addition, a standard air test shall be made immediately before use. Leather protectors shall always be worn over lineman's rubber gloves.

Rubber gloves are not to be relied upon for protection from energized circuits of more than 3500 volts to ground.

When work is performed within reaching distance of exposed electrical parts, the clothing worn by the worker shall comply with the OSHA Guidelines for the Enforcement of the Apparel Standard of 29 CFR 1910.269(1)(6).

- Note: Clothing, either alone or in blends, made from acetate, nylon, polyester, rayon or similar material is prohibited by this paragraph, unless the employer can demonstrate that the fabric has been treated to withstand the condition that may be encountered or that the clothing is worn in such a manner as to eliminate the hazard involved.

When fishing a conductive tape or wire through a conduit, personnel are to be stationed to prevent the free ends of the tape or wire from contacting energized equipment.

The cases of all portable electrical motor-driven hand tools are to be grounded by use of standard three-prong plugs and receptacles and all other electrical equipment supplied with 50 volts or above are to have their cases or frames connected to ground, except:

- Devices operated solely from self-contained batteries.
- Devices which have cases and all exposed parts protected by insulating material.
- “Double insulated” tools.
- Devices supplied with less than 150 volts to ground for which exceptions have been granted by the Safety Manager's Office of Safety and Facility Assurance.

Commutating type tools or double insulated tools shall not be operated in close proximity to volatile materials.

Welding or burning shall not be permitted in the immediate vicinity of electrical equipment unless specifically authorized by the Facility Coordinator or the assigned Inspector.

Only devices designed for voltage testing and rated for the nominal voltage of the circuit under test shall be used to make voltage checks. Test voltage indicators shall be verified immediately before and after use by application to an energized circuit or by using an appropriate test unit.

Only fiberglass or wood ladders shall be used near electrical hazards. Metal ladders should be marked with signs or decals reading **CAUTION--DO NOT USE NEAR ELECTRICAL EQUIPMENT**.

When possible, stand to the side away from the door/cover when operating (energizing or deenergizing) disconnect switches.

3. SAFETY CLEARANCE PROCEDURES (LOCKOUT/TAGOUT)

Safety clearance procedures and responsibilities (lockout/tagout) are set forth in LPR 1710.10, “Safety Clearance Procedures (Lockout/Tagout).”

4. CONFIGURATION MANAGEMENT AND DRAWING REQUIREMENTS

LPR 1740.4, “Facility System Safety Analysis and Configuration Management,” defines the Configuration Management (CM) Program. It also identifies the facilities which are under CM and defines the minimum electrical drawings required for these facilities. No changes should be made to these drawings or equipment without the changes conforming in all respects to the requirements given in LPR 1740.4.

Copies of switching diagrams for the high-voltage power distribution system (2,300 volts and above) shall be distributed to personnel on a list approved by the Chairperson of the Electrical Systems Committee. This party shall assure that corrected copies of drawings affected by modifications are promptly provided to holders of switching diagram sets. In addition, electronic copies of these diagrams will be added to the Langley Research Center’s Configuration Management On Line (CMOL) system and will be accessible for viewing and making copies (but not revising) by LaRC employees who have been assigned an appropriate computer access password. The Systems Engineering Competency has the responsibility for initiating Change Notification Sheets (CNS) for updating the electronic copies on CMOL.

It should be noted that drawings for facilities not under the CM Program may not be up-to-date and should be field verified for correctness prior to designing or implementing any changes. The following “as-built” documentation should be provided for each system/building which is not included in the CM Program:

- A control criteria document that includes sign off by the design engineers for each discipline involved and which identifies the basic interlock logic needed to assure safe and practical control for each process system.
- An overall system functional or block diagram clearly describing the engineering design intent for each system giving the function of each major component.
- System schematics and/or elementary wiring diagrams, including one-line distribution diagrams for building power systems including the building unit substation, secondary breakers, panelboards, and motor control centers.
- Individual equipment wiring diagrams and interconnection drawings showing each terminal strip connection, excluding building light and power panels.
- Panel schedules for building light and power.
- Facility location or plot plans showing all basic equipment, panelboards, motor control centers, main distribution panels, unit substations, and major facility equipment.

Underground systems, because of their high potential for damage during excavation and the associated danger to personnel performing work on these systems, have

special requirements. LPR 1740.2, “Facility Safety Requirements,” defines the requirements for “as-built” drawings.

The following cable and switch legend applies to the switching diagrams:

1000 Series - 115 KV
2000 Series - 22 KV
3000 Series – 6.9 KV
4000 Series – 2.4 KV
5000 Series – 125 VDC and 115 VAC
6000 Series – 120/208 V
7000 Series – 227/480 V
8000 Series – 4.16 and 4.6 KV (Variable Frequency)
9000 Series – 13.8 KV
9500 Series – 34.5 KV

5. EQUIPMENT SAFETY TEST AND CHECKS

5.1 TESTS TO BE PERFORMED PRIOR TO ENERGIZING OF ELECTRICAL EQUIPMENT FOR THE FIRST TIME

Initial energizing of all new electrical equipment shall be performed in the presence of the appropriate Government representative.

All power feeder circuit breakers shall be checked for adjustment and operation in accordance with the manufacturer's instructions. Molded case circuit breakers without solid state trip devices are excluded from this requirement.

All protective relays and other such devices shall be tested to verify their capability of operating in the range required. Where possible, tests shall include “loading in” at the current transformer secondaries to validate the circuitry as well as the device.

All wiring shall be field verified for conformity to the design, fabrication, and functional requirements.

All electrical equipment shall be tested in accordance with industry standards at voltage levels approved for the specific type of equipment by the LaRC cognizant engineering group. In general, the minimum acceptable insulation resistance for electrical equipment shall be the greater of 1 megohm or 1 megohm per 1000 volts of operating voltage.

5.2 PROTECTIVE SYSTEM CHECKS

5.2.1 Relay Settings

Protective relay settings shall be coordinated to provide selective tripping. The responsible electrical engineering organization shall provide the coordination. The responsible operations organization shall maintain a listing of the required settings and the frequency of periodic testing of all protective relays in use.

All protective relays on the LaRC power system shall be checked and calibrated once every two years. Every reasonable effort shall be made to perform an end-to-end test of the relay circuitry in the process of this check.

5.2.2 Circuit Interruption Devices

All circuit interruption devices shall be rated to interrupt the maximum short circuit current of the power system at the point of application of the device.

Short circuit system studies shall be made by the responsible electrical engineering organization to obtain data on short circuit interrupting duty requirements whenever large loads are added or major system changes are made which may affect the short circuit duty of the circuit breakers on the LaRC power distribution system.

Circuit breakers should be immediately inspected and checked to assure suitability for reuse after any operation in which the circuit breaker opens under short circuit or fault conditions. When a trip occurs on breakers above 600 volts, the troubleshooting process shall verify the settings of all breakers between the fault and the breaker which tripped. Molded case circuit breakers without solid state trip devices are excluded from this requirement.

All 115 kV circuit breakers shall be operated at least once every 24 months to assure satisfactory mechanical operation.

5.3 HIGH VOLTAGE INSULATION TESTING OF ELECTRICAL EQUIPMENT

High voltage dielectric testing shall be preceded by the following actions:

- Red tag the applicable circuits.
- Secure the area.
- Perform a low voltage dielectric test (Megger test).
- Perform grounding procedures.

During these tests all safety precautions listed in Section 6, Paragraph 6.9 of ANSI/IEEE 95-1977 shall be followed.

6. OPERATION AND MAINTENANCE OF FACILITIES AND EQUIPMENT

6.1 FACILITY COORDINATORS AND FACILITY SAFETY HEADS

LAPD 1700.2, “Safety Assignments,” defines the duties and responsibilities of Facility Coordinators and Facility Safety Heads.

6.2 DAILY LOGBOOK

A daily log shall be maintained at each facility which has major electrical systems. This log shall record pertinent information for each operating shift, including as a minimum: operator's name, time of entry, explanation of any equipment malfunction or unusual operation, and any special work performed on the equipment.

6.3 COORDINATION IN CARRYING OUT INSTALLATION OR MAJOR REPAIRS ON ELECTRICAL EQUIPMENT OR SYSTEMS

Prior to selecting and installing any new electrical equipment or systems, the design engineer shall consult and coordinate the work with the Facility Safety Head.

The Facility Safety Head shall be responsible for the overview of safety aspects for the repair or overhaul of major research equipment which requires partially or totally disabling of the research operations of a facility.

6.4 USE OF LIFTING EQUIPMENT IN AREAS WITH EXPOSED ELECTRICAL ENERGIZED PARTS

Where cranes and derricks are used in or around high-voltage substations, overhead lines, or exposed energized parts, the operations and equipment shall be in conformance with OSHA Subpart N, Paragraph 1926.550, “Cranes and Derricks.” (See also Chapter 7.2, “Energized High Voltage Substations,” below.)

- All lifting equipment shall be effectively grounded when being moved or operated in close proximity to energized lines or equipment. Consideration shall also be given to grounding the load, particularly if insulated lifting straps are in use.
- Lifting equipment shall be operated with a dedicated observer to warn the equipment operator of potentially hazardous situations and/or movements.

6.5 PROTECTIVE GROUNDING

6.5.1 Definition and Requirements

Equipment normally energized above 600 volts should always be considered energized unless protective grounds and/or other appropriate safety measures, in accordance with LPR 1710.10, “Safety Clearance Procedures (Lockout/Tagout),” are

confirmed to be in place. Protective grounds are temporary grounding and short circuiting conductors which are placed on deenergized electrical equipment for personnel protection. These grounds are a temporary protective measure and should not be confused with the fixed ground system required by NEC. Protective grounds are normally used to prevent accidental energizing of equipment and systems and shall be applied to any equipment when, in the opinion of the worker, the worker's supervisor, or the safety supervisor, the application is required. If protective grounds are determined to be. necessary, they shall be applied before beginning work on systems or equipment which may bring personnel into contact with parts which are normally energized at or above 600 volts.

6.5.2 Responsibility

The Safety Operator shall be responsible for testing the system to ensure that no voltage is present prior to providing safety clearance. When grounds are determined to be necessary, it shall be the responsibility of the Safety Operator to ensure that adequate grounds are placed for the protection of the workers.

6.5.3 Method of Application and Removal

Before attaching protective grounds, the equipment or circuit to be protected must be deenergized, tested to verify that the voltage is zero, and locked and tagged as required by LPR 1710.10, “Safety Clearance Procedures” (Lockout/Tagout). All conductors, static wires, circuit neutrals, and cable sheaths shall be connected in a manner which will ground all conductive portions of the circuit to a common point. The protective grounds shall not be removed until all workers are clear of the circuit or equipment. The ground end of the protective grounding cable shall always be connected first and disconnected last. Protective grounding cables shall not be less than 2/0 AWG copper or equivalent. Special requirements for some specific configurations are given below.

6.5.3.1 Overhead Lines and Pole Work

All protective grounding cables shall be connected to an approved ground point, which may be a grounded metal structure, a substation ground point, an anchor rod, or a driven or screw-type ground rod. A multi-grounded common neutral of 2/0 AWG copper or equivalent is an acceptable ground for pole work. Pole guy wires are not acceptable ground points.

Circuit conductors shall be grounded by attaching the grounded cables to the conductors, progressing upward and outward from the work point. Personnel shall remain as far below the conductors as possible, keeping clear of the grounded cables and clamps. At the completion of work, grounding cables shall be removed in reverse order from installation, keeping clear of the cables and clamps until all conductors have been ungrounded.

6.5.3.2 Transformers

Before working on transformers (see Chapter 6.15), the following shall be performed:

- Open the transformer primary disconnect switch.
- Remove the secondary fuses or open the secondary breaker.
- Check the system to verify that the voltage is zero.
- Install protective grounds.
- Install insulated barriers or boards to isolate energized studs.

Where connected transformers are in the zone between protective grounds, the primary side of the transformer shall be disconnected by either removing the line taps or opening the fuse cutouts. Where primary line work is to be performed on the transformer pole, the secondary wires shall also be disconnected or protective grounds applied. The secondary neutral, if established as grounded, may be considered as an adequate ground. On distribution transformers, the secondary neutral shall be considered an adequate ground for protective grounding, if the permanent ground is interconnected with the secondary neutral, the transformer case and a ground electrode.

6.5.3.3 Power Capacitors

A period of at least five minutes shall elapse after deenergizing power capacitor units or banks before protective grounds are installed. All capacitor units in the working area, and any other capacitor units adjacent to the working area that could be contacted, shall be short circuited and grounded. (See Paragraph 7.7 of this document.)

All individual power capacitor tanks shall be grounded. In the case of capacitors installed in banks on insulated conductive mounting racks, the racks shall also be grounded before working on the bank.

6.5.3.4 Underground Cables

Protective grounding of conductors in underground cables cannot always be performed at the point of work. Protective grounds shall be attached at the nearest location where the conductors can be reached. Conductive sheathing or shielding tape shall have a protective ground applied on both sides of the work point.

6.6 UNDERGROUND UTILITIES AND OPERATIONS

6.6.1 Confined Space Entry Permit

A LaRC approved Confined Space Entry Permit is required before entry into any manhole or vault.

For specific requirements, see LPR 1740.2, “Facility Safety Requirements,” for details.

6.6.2 General

The following rules apply when performing underground work:

- Only qualified workers shall be permitted to work in electrical manholes or cable tunnels if energized cables are present. Unqualified workers may assist in these operations if adequate supervision and safety guarding of the unqualified worker is provided.
- The conductive sheathing or shielding tape of all energized cables adjacent to the underground work area shall be verified to be grounded prior to commencing work. If ground verification is not feasible, then barriers shall be installed to prevent workers from making contact with energized cables or equipment. If neither barrier erection nor ground verification is feasible, all cables adjacent to the work area shall be deenergized.
- Manhole cover hooks, cover lifters, or recessed handles shall be used for removing or replacing manhole covers.
- Open manholes, handholes, or vault gratings shall be protected by suitable barriers or guards and adequate lighting shall be provided during hours of darkness. In addition, safety cones and warning flags shall be used to direct vehicular and pedestrian traffic around such openings.
- When practical, manholes shall be entered or exited by means of a ladder.
- When working in manholes, handholes, or vaults, one person shall be stationed on the surface, to be readily available to those working below the surface.
- Tools and materials shall be raised or lowered in manholes by means of a suitable bucket, toolbox, or rope.
- Manhole covers and gratings shall be properly seated when replaced.
- Approved lighting units shall be used when working underground.
- Air-driven tools used around energized cables shall be grounded.
- Digging permits are required for excavations of 6 inches or deeper. (Refer to LPR 1740.2.)

6.6.3 Gas and Fumes

No one shall smoke, strike matches, or permit any other type of open flame in, or in close proximity to, a manhole or vault being ventilated until tests have determined that it is safe from gases or fumes.

Before entering a manhole or vault, forced ventilation shall be provided or appropriate gas detection tests (approved by the Safety Manager) shall be performed. If gas or fumes are detected, no one shall enter the manhole or vault (except as provided for in the last procedure in this sub-paragraph, below) until thorough ventilation has been accomplished and tests made to ascertain that the gases or fumes have been eliminated.

When ventilating a manhole or vault to eliminate gases or fumes, the manholes on either side shall be opened when practical.

Except where forced ventilation is provided, gas tests shall be made at regular intervals when underground work is in progress in manholes, handholes, and vaults. If gases or fumes are detected, the manhole or vault shall be vacated promptly, ventilation started, and the condition reported to the supervisor.

If it should become necessary to perform work in a manhole or vault containing gases or fumes, no one shall enter except under direct authorization of the Safety Manager. The Safety Manager's representative shall be present and responsible for seeing that approved respiratory protective equipment and ventilation equipment are used.

6.6.4 Energized Cables in Manholes

All cables in manholes shall be considered as sources of potential shock. Tests shall be made to verify that there is no voltage between the outer sheaths and grounds.

Even though cables are shown to have no potential between their outer sheath and ground, contact should be avoided unless necessary to complete some specific item of work. High voltage gloves shall be worn unless the cable has been cleared. (See Paragraph 6.5 of this document.)

When cables are being pulled into manholes, a physical barrier should be provided to prevent contact between existing energized cables and the new cables, cable pulling equipment, and personnel.

6.7 CUTTING AND SPLICING POWER CABLES

Splicing or tapping of energized power cables shall not be permitted.

Before cutting into deenergized high voltage cables (above 600 volts) for the purpose of making repairs or removing the cables from the raceway system, workers shall also comply with the instructions elsewhere in these procedural requirements covering clearing, tagging, testing, grounding, and short circuiting, and shall also comply with the following.

Before piercing or cutting, cables shall be identified by tags, ducts, and/or duct records. Tags and ducts associated with the cables shall be checked against records. Physical checks will be made on either side of the location where the work is to be performed. When the ends of the high voltage power cable are accessible and can be "open circuited," apply a pulsating test current to the conductor and use a current measuring instrument to positively identify the cable. After the cable has been identified, either procedure "A" or "B" shall be followed to ensure that the cable is deenergized. After piercing, if no voltage is detected, the cable may be cut.

PROCEDURE “A”

Pierce the cable by using a grounded, mechanical, piercing device. The piercing device shall be installed on the cable using rubber gloves or an insulated stick and shall be actuated remotely by an insulated stick or actuating device.

PROCEDURE “B”

Rubber gloves shall be worn when removing sheathing or shielding tape, when testing for voltage, and when cutting or piercing cables.

A metallic jumper shall be installed to bond the metallic sheathing or shielding tape on each side of the proposed location for cutting the cable.

At least 10 inches of sheathing or shielding tape shall be removed for the full circumference of the cable without disturbing the insulation. The cable shall then be tested for voltage with a voltage detector. The voltage detector shall be given a reliability test before and after the voltage test.

If no voltage is detected, one-half of the insulation shall be removed. Test the cable for voltage. If no voltage is detected, the cable may be pierced.

6.8 SWITCHING

All electrical switching required for clearance to work on electrical circuits shall be performed by personnel who have been authorized as Safety Operators for the specific equipment. (See LPR 1710.10.)

Disconnecting poles (hot sticks) and rubber gloves shall be used when operating high-voltage disconnecting switches. The length of the disconnect pole for the various voltage ranges is listed below:

Voltage Range	Minimum Length of Disconnect Pole
601 to 7,500	4 feet
7,501 to 50,000	8 feet
50,001 to 73,000	12 feet
73,001 to 115,000	16 feet

Clothes, as defined in paragraph 2.4 of this document, shall be worn when operating any manually operated, mechanically connected, airbreak switch/breaker where the voltage exceeds 600 volts. This includes all totally enclosed switches above 600 volts with external handles, such as the type used on chillers, large motors, and so forth.

When work is to be performed on secondary circuits or equipment which are only disconnected from sources of power by oil switches, the following procedures shall be
incorporated into the Safety Operator Clearances Procedure, NASA Langley Form 495, associated with each oil switch being locked and tagged:

- Obtain concurrence from responsible electrical technician and the Facility Coordinator.
- Deenergize the oil switch.
- Perform tests to verify that there is no voltage on the load side of the transformer from phase-to-phase and from each phase-to-ground.
- Apply lockout/tagout(s). Indicate on the red tag(s) that no work shall be performed on the high voltage (primary) side of the equipment.
- Apply protective grounding as close as physically possible to the load side of the transformer.
- Before operating any switch used for maintenance or for isolating circuits above 600 volts, the switch operator is to be accompanied by a second person who is to stand at a safe distance and be prepared to respond in the event of an emergency. The second person shall conform to the requirements given in Paragraph 2.4 of this document.

6.9 REMOVAL OF OBSOLETE EQUIPMENT

In general, when removing old or obsolete equipment, the electrical wiring, conduit, and control boxes should be removed from the equipment to the power source. The power source should be deenergized and disconnected prior to disconnecting the load or cutting the cables.

After the equipment has been removed, the controlled electrical wiring diagrams, schematics, and so forth, shall be revised to show this change. (See Chapter 4.1.)

6.10 EQUIPMENT OPERATING PROCEDURES

Each facility with complex or high energy systems should have written operating procedures to ensure the safety of personnel and the protection of equipment. These procedures should include operating sequence, safety precautions, and emergency action required. (See Chapter 4 for pertinent drawing requirements and LAPD 1700.2, “Safety Assignments,” for requirements involving detailed procedures, records, and so forth.)

6.11 STANDBY ELECTRICAL POWER

A minimum of two 60-kw or larger diesel electric or equivalent portable powerplants shall be available for emergency use. This power shall be provided at a voltage rating of 480 volts and/or 208 volts, three-phase, 60 Hertz that will permit connections to the bus on the secondary side of building unit substations.

6.12 VALVE CONTROL SYSTEMS

Whenever valve control systems are dependent on electrical power for safe operation, provisions shall be made to have these systems operate to the failsafe position in the event of an electrical power failure.

All process system supply valves shall be “backed up” by a main cut-off valve that shall automatically operate to make the system safe in event of a control valve malfunction.

6.13 TESTING OF POWER INSTRUMENTATION

Before working on an instrument or other device in a current transformer secondary circuit, the transformer secondary circuit shall be shorted together or bridged in such a manner as to prevent opening the secondary circuit.

6.14 VALIDATION OF OPERATIONAL ELECTRICAL EQUIPMENT

Operational electrical equipment shall be periodically validated to determine that the dielectric strength has not fallen below safe levels. The responsible operations group shall maintain procedures specifying the method and frequency of the tests. A dc "Megger” appropriate to the circuit working voltage shall be used to obtain the readings. Validation is mandatory prior to energizing after any repair which may have affected the equipment insulation system. In general, power system equipment shall be tested for minimum values of 1 megohm or 1 megohm per 1000 volts of operating voltage, whichever is greater. If lesser values are obtained, an appraisal shall be made by the responsible engineering organization before the equipment is energized.

6.15 INSTALLATION AND REPAIR OF TRANSFORMERS

6.15.1 Current and Potential Transformers (Instrument)

Current transformer cases and secondaries shall be grounded.

When more than one set of current transformer secondaries are electrically connected, a ground point shall be selected that provides grounding for the network.

When the primary circuit is energized, secondaries of current transformers shall not be opened.

The case and one wire on the low-voltage side of a potential transformer shall always be grounded before energizing the transformer.

6.15.2 Power and Distribution Transformers

Whenever work is to be performed on connected transformers, protective grounds shall be applied as required by Paragraph 6.7 of this document.

When transformers are installed or replaced, the secondaries shall be checked for correct voltage and phase rotation.

When transformers are installed and before they are energized, the ground connection shall be made to the case, and where applicable, to the neutral.

Transformer covers or handhole plates shall not be removed from energized transformers.

All transformers shall be considered energized at full voltage unless they are disconnected from the primary and secondary power source, or unless they are disconnected from the primary power source and protective grounds have been applied to the transformer secondary. The opening of a fused primary cutout or switch shall not be considered as a primary disconnection unless the deenergized side of the cutout or switch is grounded.

When removing transformers, the case and neutral ground shall be disconnected last.

Because it is possible to have up to full phase-to-ground voltage on the transformer neutral, transformer neutrals shall always be treated as phase conductors, unless established as grounded.

7. SPECIAL SAFETY REQUIREMENTS

7.1 PCB HAZARD

Electrical equipment, such as transformers, capacitors, and so forth, may contain a highly toxic, noncombustible, synthetic, electrical insulating liquid known generically as “Polychlorinated Biphenyls” (PCB). PCB has been sold under various trade names including “Askeral,” "Inerteen,” “Chlorexol,” “Noflamal,” and “Pryranol.” All leaks of fluid containing PCB should be reported immediately to the LaRC Environmental Manager.

7.2 ENERGIZED SUBSTATIONS (2300 VOLTS AND ABOVE) (CONTRACTOR WORK)

The Government shall require contractors to:

- Conform to all the applicable OSHA and LaRC safety rules and regulations.
- Submit a work plan, at least seven days prior to initiating work in the substation, outlining the work to be done and identifying the circuits required to be deenergized to safely conduct operations. The plan shall include a detailed step-by-step work procedure for each phase of the work. All changes to this work plan shall be reviewed with the responsible LaRC personnel prior to initiation.
- Appoint an individual responsible for the electrical safety of each work team. The safety supervisor(s) shall attend the Construction Safety Briefing. Before the work the responsible individual shall provide a document to the Government establishing that the appointed safety supervisor(s) is (are) qualified and knowledgeable in OSHA and LaRC safety regulations and requirements.
- Request an electric power outage at least seven days in advance of the need.
- After receipt of the red tag stubs, check to ensure the designated circuits have been deenergized and properly grounded and verify that the immediate work area and a zone beyond the work area have been made safe before permitting employees to work in the substations. As a minimum, the contractor shall perform the following:

  - Install all barriers and rope guards that are deemed necessary to clearly define the work area. Barriers and rope guards shall be sufficient to restrain the workers from inadvertently moving out of the work area.
  - Establish a safe zone area between the work area and the energized parts of the substation so that all live circuits and parts clear the designated work area by at least five feet.
  - Use physical barriers whenever practical. When adequate barriers cannot be installed around all energized parts adjacent to the work area, the contractor shall take whatever action is needed to provide the continuous safeguarding of each worker.

- Assign a full-time employee knowledgeable of the safety required and without other duties to assist the safety supervisor in assuring the safety of the work area when the work involves handling of lengths of conduit, bus, steel, or large equipment.
- Assign additional safety supervisors as needed for the protection of the workers when the work is so divided and extensive that one safety supervisor cannot effectively maintain safety surveillance over the workers and their operations.
- Refrain from using any crane in or near an energized substation where movement of the crane might cause objects to fall into or strike energized parts of the substation.
- Contact the Government representative at the beginning of work each day for admittance to the substation. Maintain surveillance of the substation gates to only permit authorized personnel to enter. No entrance shall be made while work is being conducted unless the contractor safety supervisor has been first contacted to verify conditions are safe.

7.3 RULES GOVERNING CONTRACTOR CONNECTION INTO GOVERNMENT ELECTRICAL UTILITIES

Prior to permitting the contractor to make connection into any part of the Government electrical power distribution system, the contractor shall:

- Make written application to the Government Contracting Officer stating the date, time, location, and the service desired.
- Jointly with the Government representative, make the necessary checks of the contractor's system and the Government's supply to ensure their compatibility and safety.

7.4 EXPERIMENTAL EQUIPMENT

Experimental electrical equipment which is under development, and therefore subject to frequent modifications, presents a particular hazard to personnel. Operating and emergency procedures may change from day to day. The following are minimum safety requirements:

- A responsible member of the research team shall be designated to establish correct working procedures as well as proper emergency procedures. Particular emphasis shall be placed on emergency deenergizing. of the equipment.
- Areas where high energy sources are present shall be marked and physical barriers used where practical. Electrical and mechanical safety interlocks should be used where practical.
- Persons shall not work alone on high energy equipment unless the electrical equipment has been deenergized and secured in the "OFF" condition.
- Before working on high voltage/high energy equipment that has been energized and then deenergized, the equipment shall be grounded to ensure no residual voltage remains as a potential shock hazard.

- Fail safe circuits should be used, where practical, in order to minimize possible hazards to personnel and equipment.
- Temporary wiring shall meet the NEC. Indiscriminate use of extension cords and portable cables should be avoided.
- Do not use any equipment that has frayed cords or three-wire cord ends that have had the grounding prong removed. Faulty equipment and tools shall be repaired by qualified personnel.
- Do not use metal ladders when working on or near energized electrical equipment.
- Avoid wearing rings or other jewelry when working on energized electrical equipment since this presents a shock and burn hazard.

7.5 CONTROL VOLTAGE FOR DEVICES

All controls subject to “routine” operational adjustments of exposed electrical components or controls that are not packaged in a manner to preclude casual or random entry by unauthorized individuals shall conform to the NEC Article 725 for Low Energy Power and/or Low Voltage Power Circuits.

7.6 COLOR CODING OF INDICATING LIGHTS

Color caps on indicating lights designating the condition or position of the contacts on circuit breakers or switches shall conform with the following:

- Contacts closed - red.
- Contacts open - green.
- Contact automatically tripped open - amber (when finished).

Color caps on indicating lights designating the position of valves that allow flow or block flow shall conform with the following:

- Allows flow - green.
- Blocks flow - red.

The required designation as indicated here may be waived by the LaRC Safety Manager if, for reason of prior usage in a facility, it is deemed safer to use other designations. This special ruling shall require written notification and approval from the LaRC Safety Manager.

7.7 HIGH VOLTAGE CAPACITOR BANKS (EXPERIMENTAL EQUIPMENT)-GENERAL SAFETY

Test personnel conducting experiments where capacitor banks with voltages above 600 volts are employed, shall have total knowledge of the experiment, the circuit and component layout, and be fully trained in the operating and safety procedures to be used at that facility, including procedures to be used in the event of equipment failure.

The high voltage test area shall be enclosed and protected through the use of gates and interlocks on the test controls. Capacitors and related high voltage component

faults are a possible source of hazardous shrapnel. These components shall be isolated in a manner that precludes personnel injury or facility related hazards, such as fire.

High voltage warning signs shall be displayed in a conspicuous location. Flashing warning lights shall be used to indicate that tests are in progress.

A shorting switch or grounding device which normally discharges the capacitor bank should be clearly visible to the test operator.

A voltmeter (VM) connected across the capacitor bank shall be clearly visible to the test operator at all times. A redundant VM shall be installed at the capacitor banks.

Prior to touching a high voltage component within the test area, a grounding wand approved by the Safety Manager for the particular installation shall be used to verify that the capacitor bank is fully discharged.

Extreme caution shall be used on capacitor banks that are operated by dc voltages since a dc capacitor bank will maintain a residual voltage for extended periods.

Capacitors that are connected in a series to form a bank shall be treated with great care, and prior to making any changes to a test bank or circuit, each capacitor in a series string shall be properly discharged.

7.8 BATTERY AND BATTERY CELL HANDLING

Vented batteries and battery cells, regardless of electrode type, contain dangerous electrolytes which are subject to spillage. Overcharging or too rapid charging can cause electrolyte boiling and spewing, and the production of explosive gases. The following requirements shall be followed in these devices:

- Face shields or goggles, rubber gloves, and protective rubber aprons shall be worn whenever batteries or cells are being handled, filled, or charged.
- Ample neutralizing agent shall be present to fully neutralize any electrolyte spill which may occur in battery operations.
- Battery charging shall take place in a well ventilated area.
- No smoking shall be permitted in the area where batteries are handled, filled, or charged.
- Battery charging shall comply with all of the manufacturer’s recommendations.
- An eyewash station shall be within 100 feet of operations. This eyewash station can be in each facility or on the battery technician's truck. Eyewash devices must comply with ANSI Z358.1-1990.

7.9 ELECTRICAL SHOCK

Some individuals who handle electrical equipment mistakenly believe their tolerance to electric shock is related to their ability to withstand the pain of the shock. Actually, the lethal incidence is a function of current passage (duration and level) through the

heart region. Additionally, the onset of possibly lethal currents is only marginally higher than those ranked just painful and well within the range of industrial low-voltage power systems. While asphyxiation is the physiological result of the first zone of over-painful shock, the second zone results in heart ventricular fibrillation, or heart dysfunction. Not only is the latter nonself-curing on cessation of the current, but it is generally lethal within about 3 minutes. Just as it is current, not voltage, which heats a wire, it is current which causes the physiological damage. The values of 60 Hz current and its effects (typically) on an average man are listed in the following table:

CURRENT RANGE AND EFFECT ON AN AVERAGE HUMAN

Current	Physiological Phenomena	Feeling or Lethal Incidence
< 1 mA	None	Imperceptible
1 mA	Perception threshold	
1-3 mA		Mild sensation
3-10 mA		Painful sensation
10 mA	Paralysis threshold of arms	Cannot release hand grip. If no grip, victim may be thrown clear. (May progress to higher current and be fatal.)
30 mA	Respiratory paralysis	Stoppage of breathing. (Frequently fatal.)
75 mA	Fibrillation threshold 0.5 percent	Heart action discoordinated. (Probably fatal.)

250 mA	Fibrillation threshold 99.5 percent (>5 second exposure)	
4A	Heart paralysis threshold (no fibrillation)	Heart stops during current passage, restarts normally on current interruption. (Usually not fatal from heart dysfunction.)
>5A	Tissue burning	Not fatal unless vital organs are burned.

Note that as shock current values are increased they are statistically more dangerous from burn-type damage than heart failure. This is most likely because of the shorter exposure times. When very high voltages (above 2300 V) are involved, burns may not be severe as the victim initiates an arc that retracts (by reflex) the victim's attempted grasp. In summary, humans are affected in major proportion by the duration as well as the level of shock. When contact is made in such a manner as to retract the contracting part (such as a light finger touch when the strong muscular contractions of the arm pull the fingers away) the shock is much less dangerous than one of the same current level incurred by "freezing" to the contact with a full hand grasp.